BREAKBULK AMERICAS

Tides of Transition: IoT Integration for Maritime Transformation

Caleb Bihogo, David Zacher, William Day, Christian Sallese, Max Skelton

Faculty Advisors: Dr. Alfred Henson, Prof. Margaret Kidd

University of Houston

Industry Advisors: Peter Jessup, Brooks Elliott

Introduction

Maritime transport accounts for 80% of global trade but faces significant challenges from weather disruptions and outdated legacy systems that hinder efficient operations. Integrating the Internet of Things (IoT)—a network of connected sensors and devices that collect and share real-time data—offers a promising solution. This research explores how existing IoT applications, like the SAFOR Spotter Platform and Siemens MindSphere, can transform port operations, enhance weather resilience, optimize logistics, and reduce costs. Additionally, it addresses the critical challenge of integrating IoT with existing legacy systems, providing strategies and models to incorporate modern technology without requiring complete infrastructure overhauls.

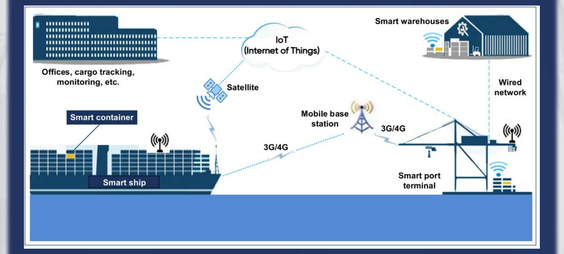

Figure 1 (Aslam et al., 2020): This figure shows how IoT connects smart ships, containers, port terminals, and warehouses using sensors and networks (satellites, 3G/4G). This integration enables real-time cargo tracking, efficient logistics, and better coordination across port operations.

Weather Disruptions

Ports often experience significant delays and financial losses due to natural disasters. For instance, Hurricane Katrina caused over $1.7 billion in damages to Louisiana ports, leading to approximately $882 million in agricultural trade losses. Such events highlight the vulnerabilities within port operations, especially since many legacy systems are not equipped to handle real-time data or provide adequate resilience during these crises.

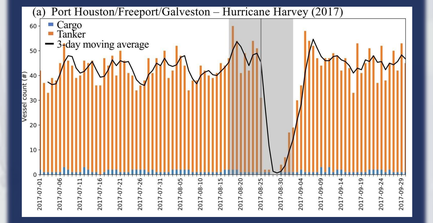

Figure 2 (Verschuur et al., 2020): Shows the impact of Hurricane Harvey in 2017 on vessel activity at the Ports of Houston, Freeport, and Galveston. It illustrates a sharp decline in the number of cargo and tanker vessels during the hurricane (shaded area), with vessel counts dropping to nearly zero. The slow rise of the 3-day moving average line after the storm demonstrates the extended time required for ports to resume normal operations.

Existing IoT Applications

Siemen's MindSphere™ Efficiency:

- **Asset Management**: Monitors equipment using sensor data to optimize maintenance and reduce downtime.
- **Process Optimization**: Analyzes data to identify and resolve bottlenecks in port operations.
- **Predictive Analytics**: Uses machine learning to predict equipment failures, enabling proactive maintenance.
- **Integrated Planning**: Connects systems for improved cargo handling, vessel scheduling, and logistics.

Figure 3 (Siemens AG): MindSphere is an open-cloud IoT system that connects assets to the cloud, enhancing digitalization and operational efficiency in ports.

SOFAR Spotter™ Platform Efficiency:

- **Connected**: Accesses real-time data via satellite and cellular, enabling two-way communication and over-the-air updates.
- **Scalable**: Lower cost than traditional platforms, with the ability to deploy at scale for dense observational networks.
- **Rapid Deployment**: Easy, hand-deployable design suited for all vessel types.
- **Durable**: Built to withstand extreme marine conditions, operating continuously with a solar rechargeable battery.

These features make the Spotter a versatile, cost-effective solution for real-time maritime monitoring.

Figure 4 (SOFAR Ocean): Shows how the Spotter reduces risks by monitoring sea conditions and providing real-time alerts for rerouting freight and cargo during threats to port infrastructure.

Proposed Model of IoT Integration

- **Process-Aware Sensors**: IoT sensors should be strategically placed and linked to specific processes.
- **Mobile Integration**: Use mobile devices to deliver tasks to the right users efficiently.
- **Task Support**: IoT should provide context-specific knowledge to aid task execution.

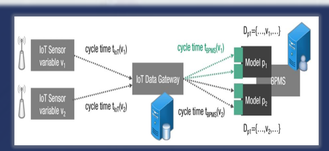

Figure 5 (De La Vara, 2020): This model shows how IoT sensor data integrates with Business Process Management Systems (BPMS) to optimize operations and reduce costs.

Case Study

At the Port of Seville in Spain, an IoT system tracks containers, improving logistics through three subsystems: CUTS (Container Unified Tracking System), FPS (Ferro Port System), and eRIO (Electronic River Information and Optimization). These systems automate data collection, track containers based on train or vessel location, and process data through a modular platform. This provides real-time cargo info, enhancing decision-making, reducing costs, and increasing customer satisfaction.

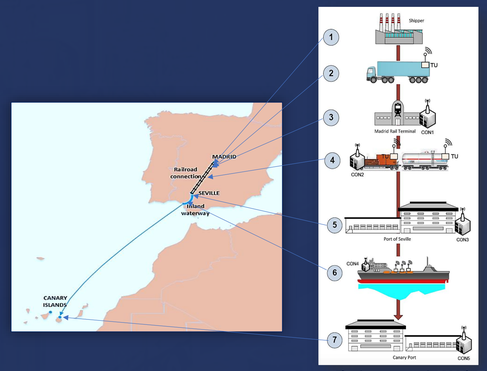

Figure 6 (Rahaman et al. 2023): The Madrid – Seville – Canary Islands intermodal corridor, a key part of Spain's transport network. It illustrates the intermodal nature of container transport, where goods are transshipped between different transportation modes at various terminals, covering significant distances.

Figure 7 (Rahaman et al. 2023): The typical sequence of managing a container shipment along the Madrid – Seville – Canary Islands corridor using the IoT system. It details the different stages of the intermodal transport chain, from the container leaving the shipper's premises to its final delivery at the destination.

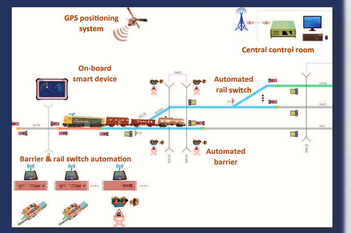

Figure 8 (Rahaman et al. 2023): This diagram illustrates the architecture of the Ferro-Port System (FPS), which automates and optimizes the management of restricted railroad networks within intermodal terminals. It incorporates elements like GPS positioning, on-board smart devices, automated rail switches, and barriers. All data is processed in a central control room, enabling the efficient coordination of train movements with minimal human intervention, thus enhancing operational safety and efficiency.

Cost-Benefit Analysis

$$OC_{tm} = M_{tm} + ST_{tm} + MN_{tm} + I_{tm} + AD_{tm}$$

Figure 9 (Stopford, 2006): Vessel operating costs can be estimated with the formula:
Operating Cost = Manning Cost + Stores Cost + Maintenance Cost + Insurance Cost + Administration Cost

At a minimum, IoT technology allows for more effective maintenance (roughly 14% of total cost) (Stopford, 2006), directly impacting the maintenance cost. With estimations of 15-20% more efficient maintenance and stores upkeep(Deloitte, 2022), simple math shows that total overall cost in this cost section alone can be reduced by up to 2.8%.

70% of surveyed organizations were optimistic that IoT integration would reduce vessel insurance costs. (Inmarsat, 2018). Within land-based transport, IoT devices have reduced some insurance costs by up to 30%. (Octagon, n.d) Research shows that improved routing alone reduces fuel use by 3-20% (Fang et al, 2016)(Roh, 2016),so the unique analytics facilitated by IoT such as routing and weather analysis allow potentially more significant insurance impacts than land transport.

Soft Benefits

Integrating IoT improves user experience by enhancing transparency and reliability through real-time data analysis. Improved preventative maintenance minimizes downtime, while optimized routing and product management reduce uncertainty, resulting in smoother and more responsive operations both at port and sea.

Future Considerations

The effectiveness of IoT in maritime operations is currently hindered by a lack of accurate data. Addressing this requires industry collaboration, operational digitization, and improved information accessibility.

Barriers to IoT Implementation

- **Labor Relations**: Automation raises concerns about job loss, potentially leading to labor disputes, such as the ILA strike.
- **Competency Gaps**: Ports need to invest in training personnel to bridge the gap between traditional operations and IT skills.
- **Security**: Balancing cybersecurity with data accessibility is crucial to protect sensitive information while enabling IoT functionality.

Recommendations

- Establishing industry standards for IoT ensures better integration and efficiency for ports.
- AI is well-suited for analyzing large datasets gathered by IoT sensors, and can quickly predict optimal routing, equipment maintenance, and weather forecasting.

References

Meet the Authors

Cullen College of Engineering
UNIVERSITY OF HOUSTON

DRIVING THE BLUE ECONOMY
TEXAS A&M UNIVERSITY AT GALVESTON

UTC Overseas

4D SUPPLY CHAIN CONSULTING

BECHTEL